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A remote monitoring system for voltage, current, power and temperature measurements

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Abstract

This paper presents a study and design of a monitoring system for the continuous measurement of electrical energy parameters such as voltage, current, power and temperature. This system is designed to monitor the data remotely over internet. The electronic power meter is based on a microcontroller from Microchip Technology Inc. PIC family.
The design takes into consideration the correct operation in the event of an outage or brown out by recording the electrical values and the temperatures in EEPROM internally available in the microcontroller. Also a digital display is used to show the acquired measurements. A computer will remotely monitor the data over internet.

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Keywords: sensors, energy measurements, microcontroller

1. Introduction

Data acquisition and processing plays an important role in the area of modern industry. System precision and performance is required depending on application areas such as domestic and medical applications. Real-time monitoring of electrical parameters is needed beside the high performance and precision of measurements with the development of modern industry towards networking.
A real-time channel of acquisition has been designed as a hardware structure based on CPU from PIC family of Microchip Technology Inc. with a maximum working frequency of 4MHz and only command cycle of 1µs. The strong data processing ability can reach 1 MIPS. That is very suitable for embedded

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systems requesting high processing ability. Data acquisition and processing has been carried out simultaneously in a periodic way. The acquisition of data is performed with three sensors: temperature, current, and voltage sensors from which the power is calculated using the microcontroller. The processing use the microcontroller while the monitoring of the data measurements is performed remotely based on Visual Basic programming over a personal computer. The paper will describe the prototype implemented to adequate measurements up to 15A load current from a 220V alternative voltage supply.

2. Sensing Board

2.1. General Overview (Fig 1)

The voltage sensor will make the translation of the alternative voltage supply into its continuous image; the power will be calculated by the microcontroller from the voltage and current sensors outputs according to the formula:

$$P= V*I \cos \varphi \tag{1}$$

The microcontroller output values corresponding to the acquired parameters then sent to the computer for monitoring via the PC serial port while they will be displayed using LCD.

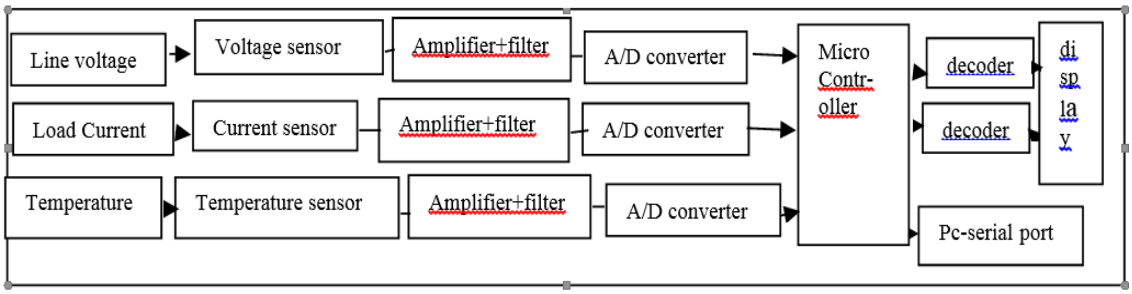

Fig. 1.General overview of the remote monitoring measurements system .

2.2. Temperature sensing circuit

The Temperature sensor LM35[[1] is a three sockets integrated circuit that has the advantage of delivering a tension as a linear function of the temperature input.(Fig.2) shows The output voltage will be amplified as in(Fig.2)

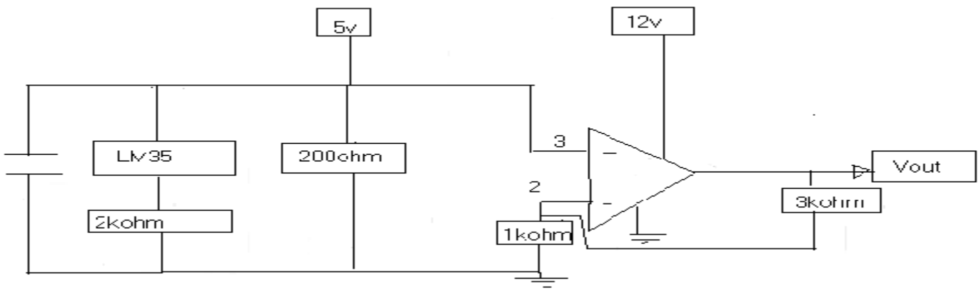

Fig.2. Temperature Sensor LM35 with amplification using the integrated circuit Amplifier 358.

2.3. Voltage sensing circuit

The alternative voltage supply will first, be transformed using a transformer from 220V- 12V Then in order to produce a 5V -DC signal for an alternative voltage amplitude of 500 V –AC, we have added a rectifier, a filter and an amplifier as indicated in (Fig.3). [2]

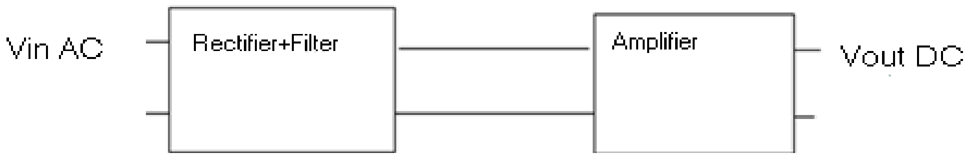

Fig. 3. Schematic Bloc of the Voltage Sensor

2.4. Current sensing circuit

This circuit transforms the alternative input current passing through the transformer into a continuous voltage output. The output function v of the current i is nonlinear for high currents but it is linear for normal values of the current .5A –AC input current is transformed into 1V output DC voltage.
(Fig.4.) shows how we shunt the output using a resistance, in order to re-establish linearity for the highest current values.
The maximum alternative current value of 15 A sensed with this circuit delivers 3V-DC. Because the microcontroller is limited to up to 5V signal, amplification will be added to the circuit in order to have5V-DC. A 4kΩ potentiometer will adjust the needed level.

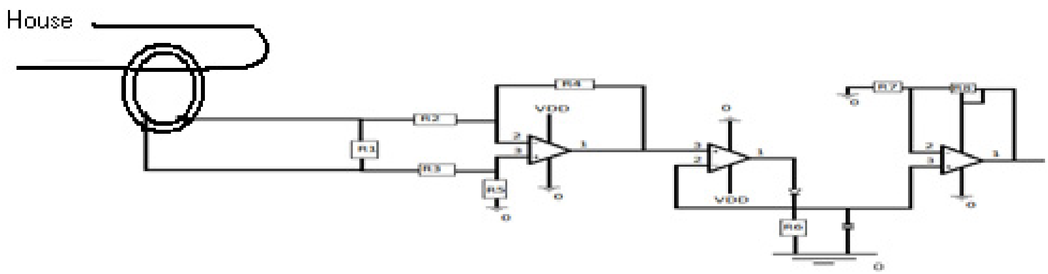

Fig. 4. Current Sensor Circuit.

2.5. Power meter

A digital power meter is designed based on the microcontroller in order to measure the power consumption of the load. The circuit diagram is in (Fig.5.) [3][4].

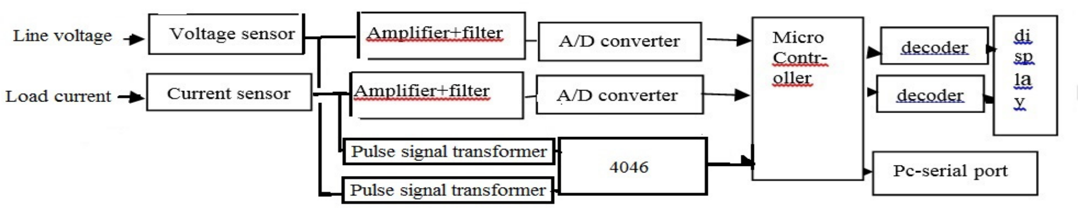

Fig. 5. Bloc Diagram of the Power meter

The power consumption of a load is given by :

$$p = 1/T \int_0^T v(t)i(t)dt \quad (2)$$

Where T is the period of the line electrical signal.
The microcontroller will receive the digital values of the current and voltage samples from the analog/digital 8 bits converter.
The average power consumption is defined by:

$$P = V * I \ \cos\varphi \quad (3)$$

Where V and I are the VRMS values of the line voltage and current .The phase φ between the line current and tension is detected by the integrated circuit 40446 B. In order to be used by the phase detector the line current and voltage are transformed into square signals as shown (Fig.5). Variations of the voltage output of the circuit versus the phase are shown (Fig. 6).

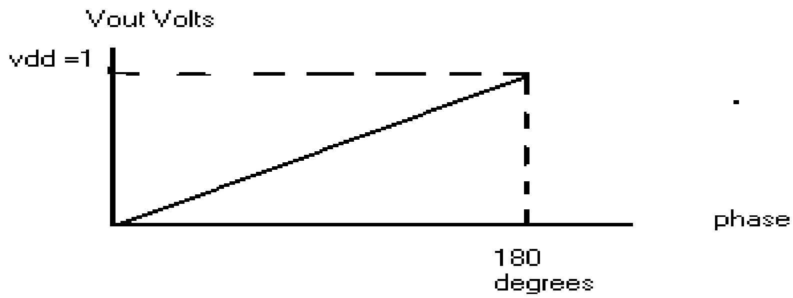

Fig. 6. Voltage response output of the Phase Detector integrated Circuit 404468B in function of the phase. Vdd is the rectified value of the voltage output Vout of HEF4046B.

2.5.1. *Phase detector: 40446B*

It is a phase locked loop detector composed of a voltage controlled oscillator VCO, 2 phase comparators with an amplifier .It delivers for each phase value a corresponding voltage.[5]
The voltage is proportional to the phase and is presented at the microcontroller input that will calculate the $\cos\varphi$ parameter.In order to keep track of the values, the output voltage of the phase detector and $\cos\varphi$ are memorized in the microcontroller's register.The bloc diagram of the phase detector is given (Fig.7).
Square signals corresponding to the voltage and current line are input respectively at pins 3 and 14, the corresponding phase between i(t) and vt) is output as an voltage Vout output related to the phase .

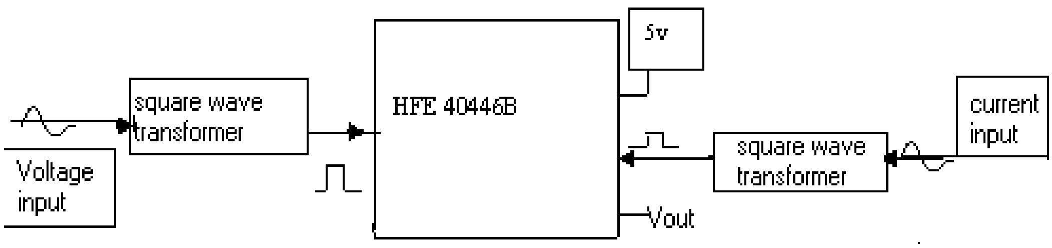

Fig.7. Phase locked loop Dector Circuit

2.5.2. Microcontroller characteristics.

The 40 pins microcontroller PIC 16 F 877A [6] is used in order to execute all the operations needed to compute the average power: $P = V * I \cos\varphi$.

Values of $\cos\varphi$ corresponding to Vout memorized in a table in the microcontroller's register are used for the computation of the average power P [5].

The power values are then displayed with LCD. This display component will present sequentially the temperature, voltage, current of the load and finally the average power consumed.

The choice of this microcontroller offer a great number of pins:

Because we need 16 pins to be connected with the LCD display component, 3 input pins to input three analogical signals from sensors then to convert them into digital signals coded with 10 bits and three other pins for the digital output.

In summary we have used:16 pins for LCD display, 3 pins to input the signals from sensors, 2 pins for the power supply, 3 pins for the command, and 3 pins for the signalization.

Pin 2 receives the tension image from the voltage sensor, pin 3 receives the current image from the current sensor, pin 4 receive the Vout from the pin 10 output of the phase detector 40446B (Fig 7).Output pins of the B port of the microcontroller are connected to the LCD in order to display the different computed values.It has a high capacity ROM of 4KB to memorize all the computation operations needed in the program, it has also a timer to synchronize the measurements and the analogical to digital conversion. (Fig.8) shows the microcontroller data acquisition system bloc diagram.

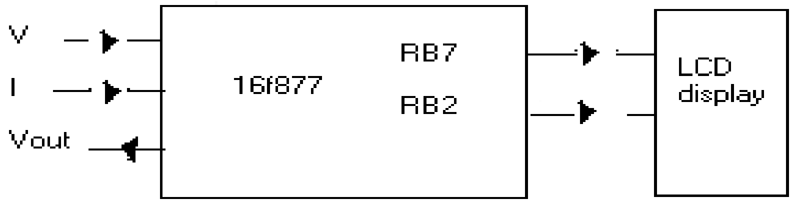

Fig.8. Microcontroller 16F877 system bloc diagram

3. Tests and Measurements

3.1. Tension image of the voltage

(Fig.9) gives the continuous tension image Vi in function of the alternative voltage Vin of the sector. As shown in the figure, Vi is non-linear at the lower values of Vin (Vin<= 20V) .

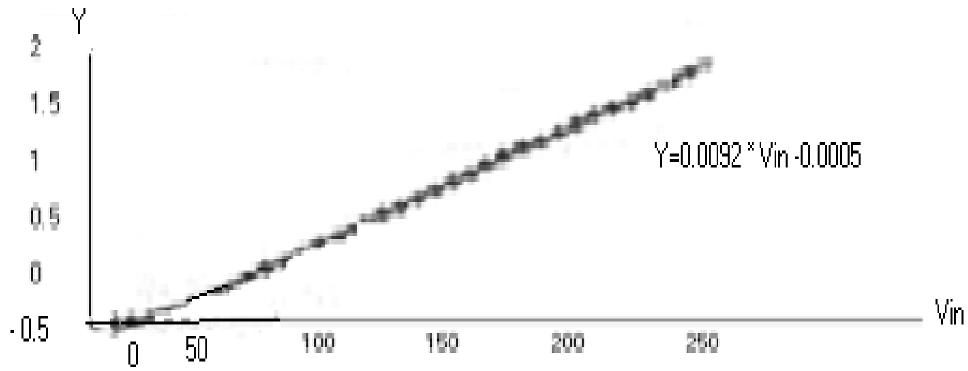

Fig.9. Tension image vi(Volt) versus the voltage sector vin(Volt) .The equation vi=0.0092*vin-0.0805 for vin>=20V has been deduced from measurements.

3.2. Tension image of the current

The current sensor used gives a tension image of 3.27V for a maximal alternative current of 15A. The microcontroller gives the decimal value of 1023 for a tension image of 5 V. In Table 1 the correspondence between the continuous value V dc of the tension image, its decimal representation, and the corresponding current value. (Fig.10) shows the variations.

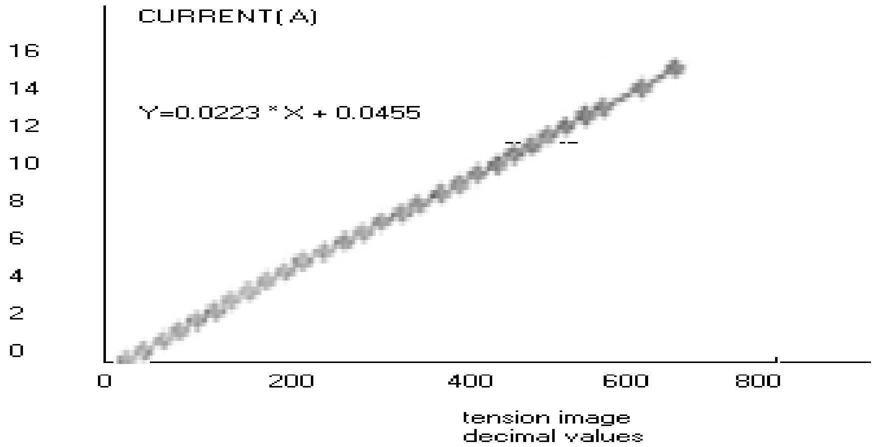

Fig.10. Variation of the current versus the decimal representation of the tension image

Table 1. Variation of the current in function of the tension image and its corresponding decimal representation.

V dc Image (V)	*Decimal V*	*Current(A)*
0.004	0.8184	0
0.112	22.9152	0.5
0.96	196.416	4.5
1.066	218.1036	5
2.5	511.5	11.5
3.27	669.042	15

3.3. Tension image of the temperature

With the temperature sensor used LM35 , for an excess of 1degree Celsius a raise of 10 mV is output. The output of 5V was adjusted for 129ºC .The decimal representation of the temperature is given in Table 2. according to the following equation given the converted decimal value of the temperature D:

$$T=129*D/1023 \tag{4}$$

Table 2. Representation of the tension image value Vdc (V), the decimal and natural representation of the temperature.

Vdc tension image (V)	*Decimal T*	*NaturalvaluesT*
3.60	737.51	93
2.82	579.00	73
2.67	545.19	69
1.90	388.58	49

4. Transmission interface

The memorized values of the different sensing entities are transmitted remotely through a wired network to a PC monitor. The data were transmitted over up to 1500 m. The transmission is done using the Internal transmission component USART of the microcontroller, and 2 interfaces MAX 485 and MAX 232 [7]..This link uses the MODBUS protocol [8]. With the RS 232 norm, along with the data, 2 same frequency clock signals, not necessary synchronized are used at both the emitter and sender end.

The normalized current 'In' acquired in real time is: with Imax=15A

$$In=I/Imax, \quad (5)$$

Values of the real time acquisition of the normalized current 'In=I/Imax' in % versus timing are computed every 17 s, using VB.net programming. Fig.(11). Shows the result **:**

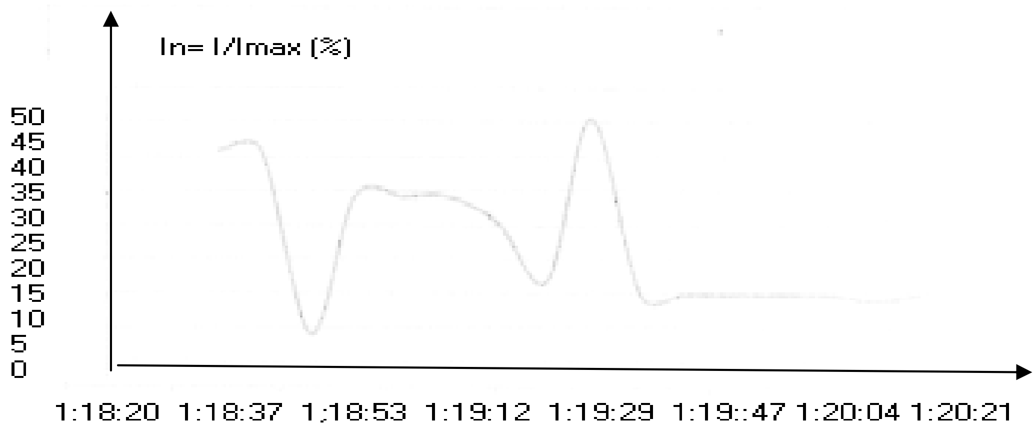

Fig.11. Variations of the normalized current measured every 17s.

5. Conclusion

the remote monitoring system acquires the temperature, voltage, current and electrical energy consumption with a microcontroller based meter and transmit them by cable in ModBus protocol. It is estimated that this system might has a production cost much lower than the imported item, we estimate the cost of this system to be around 20$. This system can be enhanced by transmitting its acquired Data over Internet using TCP/IP protocol. The application of the system is needed in the base stations related to the wireless mobile communication networks. This system controls the fuel consumption by the remote controlling of the electrical energy consumption. This system is capable of controlling remotely the excess of temperature in remote sites, by signaling the exceeded temperature.

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